V.J.1 Light-Weight, Low-Cost PEM Fuel Cell Stacks

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Objectives

- Demonstrate edge-collected stack design capable of >1 kW/kg (system level).
- Develop low-cost, injection-molded stack components.
- Verify stack performance under adiabatic conditions.
- Develop direct humidification scheme based on printed 2-dimensional (2D) microfluidics.
- Develop optimized printable current collectors for edge collection.
- Accelerate stack development by incorporation of multiple cell level sensors within the stack coupled with computational fluid dynamics (CFD) modeling.

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(B) Cost

(C) Performance

Technical Targets

TABLE 1. Relevant Technical Targets for Fuel Cell Stacks and Systems Operating on Direct Hydrogen

Metric	Units	2010 target	Status*
System Specific Power	W/kg	650	1,050
Stack Efficiency at Rated Power	%	55	40
Stack Cost	$\$/kW_e$	25	Not Determined

*Results from single-cell testing, when combined with the weight of the molded cell component.

Accomplishments

- Initial fuel cell results in single cell hardware, combined with the weight of the first generation of molded components are consistent with a stack specific power greater than 1 kW/kg.
- An enhanced fuel cell model has been developed for adiabatic operation conditions using microfluidic pathways to introduce water into the stack. Model predictions (local current density, local membrane resistance, gas phase humidities) are currently being evaluated against single cell data.
- Design limitations in the first generation molded stack components were identified and the molds re-worked. Second generation components are now available for testing.

Introduction

The benefits and limitations associated with conventional bipolar stack construction are well known. The primary benefit of bipolar construction is that it allows for low internal resistance due to the maximum conducting area between cells. It also leads to dense, highly compact stacks. However, despite considerable effort the bipolar plate still represents a daunting fabrication challenge. As a result, bipolar plates represent a sizable fraction of the weight and cost of the stack, yet ultimately, they are in-active components that do not contribute directly to energy conversion. Bipolar construction has a negative impact on stack operation as well, including water management issues related to water retention in the stack (especially critical during freeze/

thaw cycling), relatively high pressure drop and a large number of seals that must be maintained.

In response to these issues, a light-weight, low-cost proton exchange membrane (PEM) stack design is being developed that is responsive to DOE performance and cost goals and that is substantially simpler in design and construction than conventional bipolar stacks. This design is based on edge collection of current, and thus eliminates the need for bipolar plates.

Approach

The edge-collected design being pursued uses gas diffusion layers/current collectors that are fabricated by a printing process that provides an intimate contact between the various components, eliminating the need for compressive forces currently used to ensure low resistance contacts. As a result, numerous components of conventional stacks including bipolar plates, tie-rods and individual cell-level seals are eliminated, greatly reducing the parts count, weight, and assembly complexity. Low-cost, light-weight housings will be fabricated by injection molding to enclose the fuel cell components and to provide reactant manifolding. Adiabatic operation with very low pressure drop will allow for extremely low parasitic power losses due to the elimination of the compressor and substantially simpler humidification requirements. Printed microfluidic pathways (essentially 2D wicks for introducing water directly into the stack) will be an essential element in achieving adiabatic operation. Figure 1 shows the conceptual design of a 27-cell stack (ca. 150 W), which consists of four molded plates, and three sheets of catalyst-coated membrane. The dimensions of this sub-stack are 22 cm x 15.5 cm x 1.8 cm.

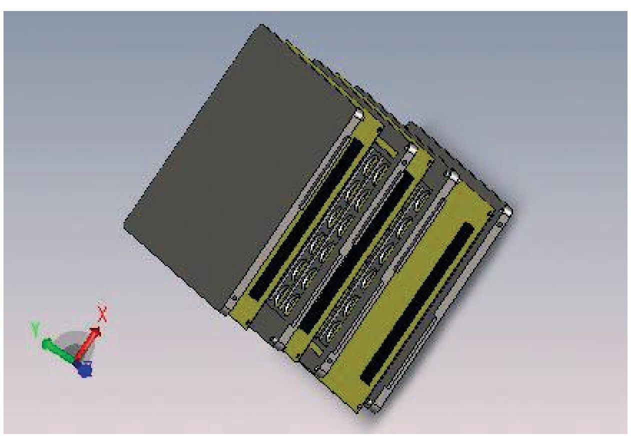

FIGURE 1. Exploded View of a 27-Cell Short Stack, Consisting of 3–9 Cell Sub-Stacks

Results

Our efforts in the first quarter of this year focused on three areas: 1) finalizing the design of the first generation sub-stack and preparing the molds and tooling necessary to produce the molded housings, 2) specifying and ordering the catalyst-coated membrane necessary for the first generation design, and 3) extending our CFD models to incorporate the cathode kinetics into the simulations.

In the second quarter of this year, we: 1) evaluated the initial molded parts for the sub-stack – several issues were identified and solutions proposed, and the necessary modifications to the molds were started, 2) we continued our CFD modeling for various operating conditions and determined that the manner in which the anode boundary conditions were being handled needed to be modified, and 3) single-cell testing of full-scale, edge-collected cells began to evaluate the effects of operating conditions.

In the third and fourth quarters of the year we developed a new fuel cell model designed to more accurately handle the anticipated adiabatic fuel cell operating conditions while continuing single-cell testing in both edge-collected and conventional configurations.

A comparison of single-cell data obtained in conventional and edge-collected configurations is shown in Figure 2. For both cases, the reactants are hydrogen and air, humidified at 60°C, and the cell temperature is 60°C. For the conventional cell, the cell area is very small, only 1.25 cm^2. For the edge-collected cell, the cell area is 18 cm^2. Under conventional conditions, the cell performance is better, due to lower

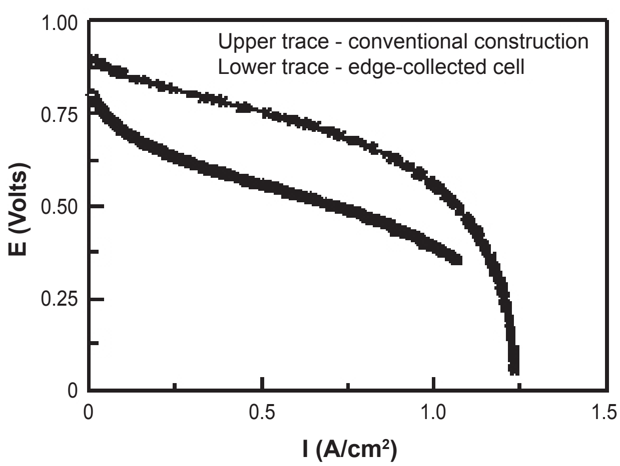

FIGURE 2. Comparison of single-cell data obtained in conventional and edge-collected configurations. For both cases, the reactants are hydrogen and air, humidified at 60°C, and the cell temperature is 60°C. For the conventional cell, the cell area is 1.25 cm^2. For the edge-collected cell, the cell area is 18 cm^2.

resistive losses in both the membrane (due to more uniform humidification) and in the current collectors (conventional gas diffusion layer and machined graphite flow field). The lower open circuit potential for the edge-collected cell is due to a combination of poor humidification and higher hydrogen crossover. The latter may be a result of the printing process used to apply the current collectors. This issue is being addressed. The CFD model predictions for the edge-collected cell under these conditions showed that the anode side of the fuel cell was too dry for optimal performance. The result shown in Figure 2 is consistent with the conclusions of the CFD model.

As a result, development of the 2D microfluidic pathways, which had been set aside earlier in the effort, has been re-evaluated. The results obtained with the new model which incorporates the microfluidic pathways suggest that the anode can be maintained well humidified even under adiabatic operation and the cell performance in edge collection significantly improved.

Conclusions and Future Directions

We will shortly be incorporating the microfluidic pathways into our single-cell test fixtures and are evaluating options for incorporating the microfluidic paths into the sub-stack hardware. We are continuing to evaluate the printed current collectors in an effort to optimize their performance – conductivity, stability in the fuel cell environment and permeability to reactants.